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**THE RELATIONSHIP BETWEEN CRUDE OIL PRICE AND THE U.S. DOLLAR  
EXCHANGE RATE**

Master's Thesis in Finance

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**ABSTRACT**

There is a wide range of studies indicating a link and a co-integrating relationship between crude oil prices and exchange rates. The previous literature mainly agrees on the strong linkage and the causal relationship between the variables moving from crude oil to exchange rates. On the other hand, there are significant results also indicating the reverse, exchange rates preceding crude oil prices. The aim of the thesis is to test whether a link and a co-integration between the variables exists. In addition, the causality will be tested.

This thesis focuses on two different crude oil benchmarks and the exchange rate of U.S. Dollar against two major oil exporters, Canada and Norway. The benchmark oil prices Brent Crude and West Texas Intermediate are chosen. These benchmarks co-move and follow closely each other. The time period investigated runs from January 2<sup>nd</sup> 2006 to August 28<sup>th</sup> 2016. The methods used for the investigation include Engle-Granger two-step method, Granger Causality test and the Error Correction Model (ECM).

The results indicate the existence of a strong and significant negative relationship between the crude oil prices and the U.S. Dollar exchange rates. Co-integration between the variables is found. The Granger Causality test indicates bidirectional causal relationship between the crude oil prices and exchange rates whereas the other causality test, the ECM, exhibits results that support the unidirectional causality running from the crude oil prices to the exchange rates.

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**KEYWORDS: crude oil, exchange rate, correlation, causality, co-integration**



## 1. INTRODUCTION

The world is reliant on oil. It is one of the key drivers of the economy and industry. Oil in its refined forms like in fuel is crucial in the manufacturing industry for logistics and everyday life for workers for commuting. As a strategic and scarce resource it attracts investors, producers, consumers and political decision-makers. Therefore crude oil has a significant role in the society.

Oil is an interesting commodity in its unique and rather irreplaceable nature. Yet, there are substitutes and alternative sources of energy available but crude oil still counts for the most commonly and widely used source of energy. The predictions of the future state on the oil consumption indicate even larger amounts consumed than today despite the simultaneous predictions of the world running out of oil and the serious environmental concerns and the restrictions the environmental threats have resulted (IEA, 2016.)

The crude oil market has faced major changes in the timeline of its existence. Verleger (1987) explains the evolution of the oil market from the 1960's controlled market to the volatile market it had turned into after the two oil crises in the 1970's and especially after the latter one in 1979. Up until the 1970's the oil market had been stable and predictable. According to Verleger, the stability and predictability resulted from a smaller amount of major oil companies that could exercise strong control over the flow of oil to the market within their integrated network. The change in the nature of the oil market started to show after the second oil crisis of the 1970's. In 1979 the crude oil prices doubled in a relatively short period of time due to a decreased output. In reality the worldwide shortage was not as severe as could be justified by the actual supply but the uncertainty drove the prices up. Oil prices have been increasingly volatile ever since because of the frequent and uncertain shifts of demand and supply of oil.

Several other studies on the determining forces of oil prices have been done in the past and they have remarked changes in the history of oil market. The major changes

concern the nature of the market in terms of predictability and volatility. By studying the demand and supply curves of oil from 1945 to 1995, Stevens (1995) concludes that up to the 1980's the market was driven by distinct and clear supply and demand curves and poor transparency in the prices. The change in the pricing pattern happened in the 1980's and during the decade the previous pattern started to break down. The result was less of a chance for the previously dominating oil companies and price makers to control the oil prices. The oil market was not controllable anymore.

Along with oil, exchange rates and currencies play a significant role in the economic world. The U.S dollar is the most used currency internationally and it holds a place as the world's primary reserve currency. The most used exchange rates are denoted always against the U.S. dollar. The dollar is the standard unit in the commodities markets, such as gold and gas in addition to oil and petroleum.

Together, crude oil and currencies create an interesting combination. They are closely connected through their impact on real economy. The oil market keeps developing, new forms of oil usage appear and oil is used in plenty of the materials around us in its different refined forms. Investors and the parties of oil trade monitor the changing oil prices closely from day to day. Both the foreign exchange and the oil market are dynamic and also often uncertain and unpredictable.

### 1.1. Background and motivation

Oil prices have recently been especially under the loop because of the volatility of the price of crude oil. From 2014 the oil market has gone through dramatic changes and the outlook for the market has turned upside down. The price level of oil had stayed relatively stable and record-high for years and started declining in the mid 2014. First in January and then again in February 2016 the WTI price hit the lowest point in years by being below 27 dollars per barrel.

Crude oil prices are determined in U.S. dollars. International crude oil trading is invoiced in U.S. dollars no matter from which part of the world the crude oil is extracted. The price of crude oil can change a lot even in a short period of time. The volatile nature of the oil market creates challenges for example to oil refining companies.

The latest sustainable innovations and concerns on the environmental aspects of oil don't seem to destabilize the role of oil as the main energy resource. OPEC estimates in its latest World Oil Outlook that oil will remain its position for at least the next 25 years to help satisfy the world's continuously growing energy needs. The center of the energy consumption and need has moved from developed countries to developing countries, as they are growing fast in population and moving out of poverty. The role of OPEC in the oil industry will be covered later in the thesis. (OPEC WOO, 2015.)

What do oil price movements then have an effect on? The oil price volatility has been associated with unemployment, industrial production, price levels and wages. Oil price increases have been found to decrease the real wages of workers. In some cases oil price movements have explained unemployment rate movements. Also, it has been suggested that there is a non-linear relationship between oil price changes and the GDP growth. All these factors are concrete examples that touch the everyday life of the majority of the population. (Lizardo & Mollick, 2010.)

Oil price movements not only affect individuals through price levels and the unemployment rates or businesses through unexpected changes in profits. The impact of oil price volatility is concrete on the state level too. Lower oil prices might increase the risk of political disturbances and fiscal imbalances in countries that are reliant on oil export. Suppliers dependent on export revenues will be hit.

Along with the effects of oil price movements on the real economy, the effects on the financial markets can be found. The previous main studies investigating the relationship of oil prices and exchange rates mostly agree on a negative relationship between the components. Golub (1983) and Krugman (1983) brought up the idea on why the oil

price movements should affect exchange rates. They both state a later widely accepted theory that an oil exporting country might face exchange rate appreciation when oil prices rise and depreciation when the oil prices fall.

Even though several studies after the first ones have supported the view presented by Golub (1983) and Krugman (1983), the more recent research emphasizes the significant link between oil price movements and exchange rates. These studies suggest more modest effects of oil price movements on the exchange rates and leave behind the idea of oil price movements as a clear explanatory factor of exchange rate movements.

As the link between crude oil prices and exchange rates has been broadly established, it can also be the changes in the exchange rate that have an effect on the crude oil prices. Results indicating the movement from exchange rates to crude oil have been provided by Sadorsky (2000) and Yousefi & Wirjanto (2004).

The motivation for writing the thesis stems from the nature of oil as a volatile and crucial commodity. Also the recent extreme price decline that hit the bottom in the beginning of 2016 with its effects on the economy brings more twist to the current topic. It is interesting to see if it possibly has had a stronger effect on exchange rates or on the other hand, is the effect significant at all.

## 1.2. Objective of the thesis

The objective of the thesis is to provide an addition to the investigation of the effects of the oil price movements on exchange rates and vice versa. There is a broad range of previous studies on the topic and especially on the U.S. Dollar exchange rate specifically, but they provide somewhat differing results. Not all the results are in line with each other. The aim of this thesis is to provide updated information and analysis on the relationship with recent data and about the possible steeper effects resulting from the

big events, like from the strongly decreased oil prices that started falling in 2014 and hit the lowest values in the beginning of 2016.

Also, many studies concentrate only on either Brent crude oil or West Texas Intermediate and on a certain set of exchange rates. In many cases the exchange rates are currencies of major oil importers against the U.S. Dollar. This thesis will be taking into account both major oil benchmarks, Brent and WTI. The exchange rates used are the U.S. Dollar against two major oil importers' currencies, the Canadian Dollar and the Norwegian Krone. The aim of using two crude oil benchmark is to possibly find differences between the effects of exchange rates on the benchmark oils or vice versa.

### 1.3. Hypothesis and expected results

Considering the literature and the numerous studies investigating the relationship between the oil price movements and exchange rates suggesting a significant link between them, it is expected that this study will show similar results. The first hypothesis is set on a fundamental level. The first hypothesis suggests the following:

*H1: There is a significant link between crude oil prices and exchange rates.*

After finding significant a link between crude oil prices and exchange rates, to continue the investigation of the relationship between the oil prices the second hypothesis suggest the following:

*H2: There is a negative relationship between the exchange rate and crude oil prices.*

The second hypothesis specifies the type of the significant link between the variables. The hypothesis predicts that a negative relationship will be found. This means, that as the exchange rate appreciates, the crude oil price depreciates or vice versa. Many

studies confirm the second hypothesis. Negative relationship is found for example by Yousefi & Wirjanto (2004), Cifarelli & Paladino (2010) and Lizardo & Mollick (2010).

The third and the fourth hypothesis are following:

*H3: Movements in crude oil prices cause changes in exchange rates.*

*H4: Movements in exchange rates cause changes in crude oil prices.*

The third and the fourth hypothesis can be tested with a causality test. The test can be applied as a two-way causality test. The results will indicate whether or not the causal relationship is unidirectional, bidirectional or if there is no causal relationship either way. The predictive power of the other variable on the other variable will be discussed.

The main view on the relationship between crude oil and exchange rates is that changes in crude oil prices affect exchange rates. On the other hand, other studies show significant results for the causality from changes in exchange rates to changes in oil prices (Sadorsky 2000; Yousefi & Wirjanto 2004).

In addition, the co-movement of crude oil prices exists. Studies show that the prices of Brent crude and WTI co-move and a long-term equilibrium exists between them (Hammoudeh, Thompson & Ewing 2008; Reboredo 2011 & Fattouh 2010). The co-movement of the crude oil prices will also be shortly discussed.

#### 1.4. Structure of the thesis

The structure of the thesis will be following. After the introduction the theoretical background will be covered. After that in the chapter 3 I will present the previous literature concentrating on the effects of crude oil price and exchange rate movements. Chapter 4 will cover the used data and the methods to test the presented hypotheses.



After that, in chapter 5, I will go more into the empirical analysis and present the results and interpret them. The last chapter will cover the conclusions.

## 2. THEORETICAL BACKGROUND

The 1970's were a clear turning point in the history of oil. After the oil crisis in 1973 the price of oil has been volatile due to the new regime in the global oil market for crude oil, where oil prices have been free to fluctuate in response to the forces of supply and demand (Baumeister & Kilian 2016). International Energy Agency (2016) assumes in its Medium-Term Oil Market Report that in 2016 the oil market will truly be free for the first time.

### 2.1. Fundamentals of the oil market

There are different types of crude oil in the market. The two most widely used oil benchmarks, both in the market and in research, are Brent Crude (Brent) and West Texas Intermediate (WTI). Other benchmarks are for example Urals and Dubai/Oman and they are named after the part of the globe they are extracted. Brent Crude counts for two-thirds of the oil traded in the world (IEA 2015.)

Brent Crude is extracted from the North Sea and it is a sweet light crude oil that is suitable for petrol and middle distillates production. The lighter and the lower the sulphur concentration is, the easier it is for the refineries to use. That is one reason why the lighter crude oil types are generally more favorable. Brent is mostly refined in Northern Europe due to the extraction location. As it is extracted underwater, it is easy to transport even to distant locations by sea.

The other most widely used benchmark, the WTI, is also a light sweet crude oil that is ideal for gasoline refining. On the contrary to Brent, WTI is extracted from soil on land in the USA. Pipelines are used to deliver the oil and it is somewhat more expensive to ship to distant locations. Therefore it is mostly consumed in the USA.

Oil as a major commodity has an impact on several aspects/components of the real economy. Hamilton (1983) has investigated the reasons for the recessions after the Second World War until the early eighties. The results of the study suggest that seven of the eight post-war recessions in the USA have been preceded by a dramatic increase in the crude oil prices. Oil price increases were followed by an output decline with a lag of three to four quarters. He finds a systematic relationship between crude oil prices and output both for a period after 1973 until the 1980's and for another data set of 1948-1972. (Hamilton 1983.)

## 2.2. Pricing dynamics of crude oil

The efficient market theory is one of the core ideas in pricing. The concept of efficient market is that both financial and commodity markets absorb all available information and use it for correct and adequate pricing. There are three levels of efficient markets and they are divided by the type of information considered in pricing. Fama (1970) introduces three levels of market efficiency. First, strong form of market efficiency considers all available information including private information making profiting from insider trading impossible. The second type is the semi-strong form that uses all public information and reflects that in pricing. The third, the weak form of market efficiency only reflects historical prices.

Economists, decision-makers and analysts have different views on the factors that determine the crude oil prices. The main factors seem to be general market conditions and speculating, resource scarcity and the cartel behavior of the oil market.

### 2.2.1. Supply and demand

Oil supply refers to the crude oil production. Despite the environmental problems and the negative climate aspects the demand for oil has increased. IEA (2016) has claimed in its latest forecast that the gap in the demand for oil between OECD and non-OECD

countries has increased and will do so also in the future. At the moment the emerging Asia and more particularly China is the major source of the demand growth. The strong world demand, along with the failure of global production increase has been explanatory factors of the strong pressure for oil prices to increase in the 2000's (Hamilton 2008).

At the moment, the production has been continuously on a high level. OPEC countries are providing oil supply with a high volume despite the current worldwide oversupply. OPEC hasn't been able to pull through binding contracts on lowering the production level. Iran was previously in embargo and was freed from it in January 2016. Iran now actively participating the crude oil market has increased the supply of crude oil. At the same time, demand has lately been stiff and lower than what was expected.

The classical microeconomic view suggests that the supply and demand of crude oil determine its fundamental value and the price fluctuations have been seen as the barometer of the worldwide economy. Yan (2012) supports the traditional understanding on the price movements. He suggests, after reviewing historical oil price fluctuations, that the basic factors affect the fluctuating prices among other factors such as geopolitical instability. Results show a clear and obvious effect of supply and demand on the oil prices and the effect is constant and self-adjusting.

Basher, Haug and Sadorsky (2012) find that oil prices have a negative relationship with oil supply. After an unexpected increase in oil supply, oil prices respond negatively to the movement. Also, oil prices respond positively to an unexpected increase in demand. Their findings support the demand and supply model for the oil market. As oil is a very price elastic commodity, every movement in the consumption or production side has an impact on the pricing.

On the contrary, Kilian (2009) points out that the demand and supply shocks are distinct drivers of the oil price. Concentrating on USA, the different shocks have different effects on the prices and also the global demand shocks might have direct and indirect effects on the US economy. The study shows that an increase in the precautionary

demand of crude oil causes persistent and immediate increase in the real price of crude oil whereas an increase in aggregate demand for industrial commodities in general cause a delayed and sustained increase in the real prices of crude oil. Kilian (2009) states that the real oil prices have been driven by the combination of global aggregate demand shocks and precautionary demand shocks instead of oil supply shocks. According to him, the traditional approach of linking major oil price increases to shortfalls in crude oil production (supply) should be revised.

#### 2.2.2. OPEC

OPEC stands for Organization of the Petroleum Exporting Countries and the organization aims to unify the petroleum policies for its member countries and ensures stabilization of the oil markets including sufficient and efficient supply of oil to consumers and a steady income for the producers. Also, the organization wants to provide a fair return for the investors in the oil industry. OPEC is an international cartel and its member countries are Algeria, Angola, Ecuador, Indonesia, Iran, Iraq, Kuwait, Libya, Nigeria, Qatar, Saudi Arabia, United Arab Emirates and Venezuela. The member countries regulate the world oil production based on the assessment of the market's oil demand.

The OPEC countries produce the most of the world oil, about 40% of the total production (IEA 2015). As the leader of the oil productions, OPEC countries have traditionally thought having the power of influencing the oil prices through the leading production levels and the central position in the market before the 1986 collapse of the OPEC pricing system.

The effect of the OPEC policy decisions and news announcements has been studied. The study of Wirl and Kujundzic (2004) claims that after controlling the oil prices before and after the cartel's announcements from 1986 onwards, the role of the cartel's influence on the oil market and the prices has diminished. Yousefi and Wirjanto (2004) on the other hand show results that within OPEC, the role and power of Saudi Arabia in price setting seems to be differing from the other members. Applying several different

measures, Saudi Arabia dominates the price setting and the other member countries take the price lead as given and base their own pricing accordingly. The price that Saudi Arabia sets is not considerably influenced by any other member country's prices. Saudi Arabia's share of market seems to be large enough to give the country such a position in the pricing.

Schmidbauer and Rösch (2012) study the effect of announcements of the world oil production levels on oil price expectation and volatility. They find that the pre-announcement period of the WTI oil price changes is volatile. Especially pronounced the effect on volatility of the prices is in the case of decision to cut or maintain the current production level.

OPEC pricing monopoly is often named as one of the reasons and driving forces of crude oil prices. Especially strong the role of OPEC is when the price pressure is upwards. In the summer 2008 the high price of oil was partly caused by OPEC monopoly (Hamilton 2008). According to IEA Oil Trends Analysis of 2015, OPEC countries haven't increased production during 2013-2014, whereas other oil producers, especially OECD countries and North America have. The latest news published in the beginning of 2017 regarding the OPEC decisions report that OPEC has agreed to cut the production.

### 2.2.3. Price fluctuations

Oil price shocks refer to an unanticipated or surprise component of an oil price change. The oil price shocks are important for policymakers and economists because the shocks affect economic decisions. For commuters the gasoline prices are crucial. Having little choice on the consumption of gasoline they have to pay higher gasoline prices if oil prices unexpectedly rise. This affects their discretionary income by decreasing the amount for other consumption. This basic transmission mechanism links oil price shocks to macroeconomic outcomes such as output and inflation. (Baumeister & Kilian 2016.)

Baumeister & Kilian (2016) present the causes of major oil price fluctuations since the oil crisis in 1973. The problem in anticipating the future evolution of the oil prices stem from the determinants of the prices, such as the demand shifts associated with the global business cycles, the shifts in global oil production and shifts in inventory demand. Forming oil price expectations for the future is difficult because the shifts are unexpected and unanticipated.

Gormus & Atnic (2016) extend the previous studies on the impact of oil prices on macro economy. They concentrate on the impact of the oil price volatility and its effects on the U.S. economy's macroeconomic factors. They test unemployment, wage, GDP and inflation in addition to incorporate gold prices, the stock market and the exchange rate independently using vector autoregression (VAR) approach. Gormus & Atnic (2016) confirm the importance of Brent oil prices in co-moving with US refined product prices. They find that in the short run, Brent oil price hikes positively correlate with wages and inflation while in the long run the positive impact can be only seen in inflation.

Hamilton (2008) explains the changes in crude oil prices. The study approaches the crude oil price movements from three angles. The first takes a look at the historical data of the basic correlations, the second angle involves economic theory on expected oil price movement behavior and the third aspect takes into account the determinants for demand and supply. The resulting notes and outcome exploring the reasons for the crude oil price fluctuations tell that historically, the price changes have been permanent, difficult to foresee and at different points of time, the change has been governed by very different regimes. To conclude, Hamilton points out a couple of major reasons for the crude oil price movements from 1970 until 1997. The reasons are the peak in U.S. oil production, the low price-elasticity of the short-run demand and supply and the vulnerable nature of the supplies to disruptions.

### 2.3. Fundamentals of exchange rates

The exchange rate market is the most liquid market in the world. Exchange rates are transparent, so the market is constantly on the right track with the actual prices. The exchange rates are measured in currency pairs. For example, the currency pair EUR/USD tells how many US dollars one could buy with one Euro. If the value of Euros increased, also the currency pair exchange rate will increase and vice versa.

In terms of empirical modeling, exchange rates are the most difficult variables in macroeconomy. The lack of sufficient and satisfactorily models has been a problem among the traditional exchange rate models (Amano & van Norden, 1998).

#### 2.3.1. Purchasing power parity and the law of one price

The purchasing power parity (PPP) is an alternative to using market exchange rates. PPP assumes that a basket of goods would cost the same number of a currency to buy another currency, as it would cost to use the currency to directly purchase the product. The relative purchasing power parity is formed as following:

$$(1) \quad S = \frac{P_1}{P_2},$$

where

S=the exchange rate of currency 1 and currency 2

$P_1$ =currency 1

$P_2$ =currency 2

PPP is useful when making comparison between two different countries' standard of living instead of gross domestic product (GDP). GDP is not always a reasonable measurement for the comparison because the price levels of two different countries may



differ a lot. The Big Mac Index is well known and widely used explaining the case. Dividing the price of a Big Mac in one currency by the price of a Big Mac in another currency forms a Big Mac PPP exchange rate. According to the theory, the formed exchange rate can be compared to the actual exchange rate in the market. If it is higher than the market rate, the first currency in the equation is over-valued and on the contrary, if the value is lower, the first currency in the equation is under-valued.

In comparison with PPP that is an aggregate measure of goods and services consumed, the law of one price refers to a theoretical situation where a single product or service costs the same price regardless of the country it is sold in, taking into account the exchange rate. The law applies to a certain time when the prices are the same at the very same moment because the prices are continuously moving in the liquid markets. The law of one price is the base for purchasing power parity. According to the theory, the market participants would adjust their prices

Exchange rates are sensitive to disturbances in the market. Zhou (1995) finds the major reason among different sources of disturbances for the real exchange rate movements. Oil price fluctuations are the main reason explaining real exchange rate movements, their role is larger than for example some macroeconomic actions such as fiscal policy's or productivity shocks.

Several other studies on the topic share the same results. Using data from different country combinations, for example G7 countries, 16 OECD countries and Germany, Japan and the USA, the results support each other. Chen and Chen (2007) study G7 countries by using monthly panel data from 1972 to 2005 and include different measures of oil prices. They find that real oil prices have been the dominant source of movements in the real exchange rates. Similar results have been found in studies by Amano and Norden (1998) and Chaudhuri and Daniel (1998).

## 2.4. Oil price co-movements

Many researchers have put effort in finding evidence explaining the question if the crude oil markets are regionalized or globalized. There are several types of crude oil differing in quality, character and in the geographical extracting location. However, the oil market is often seen as a one big market. There general idea of the market seems to consider it as a globalized, unified market. (Fattouh 2010.)

Hammoudeh (2008) addresses the question whether the crude oil market is unified or not. The results of the study indicate a long-term equilibrium relationship between a variety of different oil benchmark prices. Continuing to provide supporting evidence on the globalized oil market, Fattouh (2010) investigates a couple of different oil streams, such as Mexican Maya, WTI and Algerian Saharan Blend. The selection gives chances to investigate times series combining different and similar characters of the crude oils, such as a combination of two heavy crudes and a heavy and a light crude oil. The results from a two-regime threshold autoregressive model show, that the crude oil markets are linked though at a general level. The prices of crude oils might develop independently for some time but the deviation from the other crude oil prices is limited. The findings suggest that oil price differentials follow a stationary process and also that markets are not necessarily integrated in every period of time.

Reboredo (2011) addresses the same question whether the crude oil markets are globalized or regionalized. With a new approach of dependence structure by using several copula model specifications with four major crude oil benchmarks, WTI, Brent, Dubai and Maya, Reboredo suggests a supporting view in favor of the globalized oil markets. According to the study, crude oil prices are linked with the same intensity during bull and bear markets.

### 3. PREVIOUS LITERATURE

This chapter presents the literature concerning crude oil prices and the evolvement of the point of view in the oil price research field. During the volatile and free-floating oil price era, the focus of the studies has moved from a larger scale macroeconomic aspect to more specific effect on exchange rates.

#### 3.1. Effect on economic activity and the stock market

The effect of crude oil price movements along with the role of oil determining the state of the economy has been majorly studied. Many researchers and economists undoubtedly state the importance of oil as a measure of wealth. The trend in research on the effects of oil price shocks has moved from the macroeconomic point of view to the view on stock returns. Still it seems that the larger literature concentrates on the economic activity but in the last couple of years the research on the oil price fluctuation effect on stock price returns has increased.

After the oil crisis of 1973 the research on oil price fluctuations concentrated on the effect on economic activity and macroeconomic performance. Hamilton's (1983) research has been one of the first one to study that relationship. He finds strong evidence that an increase in oil price leads to a decline of the real gross domestic product in USA.

Hamilton's (1983) research has been extended and used as a base study for further investigation. By the influence of one of the first studies on the topic, also for example Kilian (2008), Cunado and Perez de Garcia (2005) and Gronwald (2008) confirm the findings of Hamilton (1983). Kilian (2008) suggest a negative relationship between oil price shocks and aggregate activity in the G7 countries (Canada, France, Germany, Italy, Japan, the United Kingdom and the United States), Cunado and Perez de Garcia

(2005) find the same effect in six Asian countries on both economic activity and consumer price index and Gronwald (2008) again in USA discriminating large oil price changes from normal ones and concentrating on the large ones.

The link between the two major views, the effect on economic activity and on stock markets, is strong. GDP, unemployment rate and inflation are factors that indirectly affect the stock market. Corporate profits decline as for example unemployment increases affecting the cash flows. Today we have several studies proving the connection between oil price movements and stock market returns.

Before the mid 1990's little research had been done on the connection between the oil price movements and stock market. Jones & Kaul (1996) contribute to the theme in their study testing the rationality of the stock price reaction. They use quarterly data from 1947 to 1991 in the U.S., Canada, Japan and the U.K. for their regression. The study shows that especially U.S. and Canadian stock markets are rational, since their reaction to oil price shocks can be justified by current and future changes in real cash flows. The results imply that oil prices affect the aggregate stock returns in the U.S. and in Canada.

Even though the evidence on the negative relationship between oil prices shocks and stock market returns is strong, there has been a lack of consensus on the relationship between oil prices fluctuations and stock prices. On contrast to the study by Jones & Kaul (1996), for example Huang et al. (1996) find opposing evidence in the 1980s data. Using daily data on oil price futures from NYMEX and stock return indices, such as S&P 500 in the vector autoregressive (VAR) approach to examine the lead-lag relationship between the oil price futures and the stock indices, Huang et al. (1996) find no correlation between them, except for oil companies.

Turning the attention from the effects on macroeconomy to stock market, Sadorsky (1999) has also made major findings. Sadorsky (1999) states that changes in oil prices impact economic activity, but not vice versa. This impulse response suggests that oil price movements explain stock return movements. Positive oil price shocks reduce real stock returns as real stock return shocks positively affect interest rates and boost

industrial production. Using VAR model, Sadorsky (1999) finds that oil prices and the price volatility have significant effects on real stock returns.

After the 1990's researchers have expanded the investigation. Lee, Yang & Huang (2012) study oil price shocks' impact on G7 countries sector indices. Dividing the equity market into sectors can provide more accurate results on the actual effect since oil prices may affect different sectors in different ways.

Most of the studies focus on the short-term effects and some of them indicate insignificant results for the longer period, like studies by Park & Ratti (2008) and Sadorsky (1999). To extend the literature on the longer-term effects, Miller & Ratti (2009) analyze the long-run relationship between the crude oil price and international stock markets from 1971 to 2008. They find a significant relationship in two longer time periods, from 1971 until 1980 and from 1988 until 1998. After that the relationship seems to have changed and stock markets do not respond to oil prices as expected based on previous relationships. Though the evidence supports the view that stock market prices increase as the oil prices decrease and decrease as the oil price increases.

It seems that the severity of the oil price shocks and volatility affect the results when investigating the relationship between the oil prices and stock returns. By using the daily S&P 500 and WTI oil transaction data, Lee & Chiou (2011) find that significant oil price fluctuations result in negative impact on the S&P 500 returns. This result did not hold for weaker oil price fluctuations. The stronger the movement, the stronger the effect on the stock returns.

Most of the studies on the relationship between oil prices and stock markets concentrate only on developed economies, oil exporters or importers or on limited term structure. To update and improve the existing literature, Le & Chang (2015) contribute by examining a mixture of the different characters of oil economies. They include an oil-refining economy Singapore, an oil exporter Malaysia and an oil importing and oil reliable country Japan aiming on generalizing the results between them.

### 3.2. Correlation between oil price the exchange rates

There is a clear link between the crude oil market and the currency market. Previous major studies show a strong correlation between the state of the economy, stock market prices and crude oil prices. Inevitably also exchange rates have a role in the oil market and the correlation has been studied by using the data from oil-exporting countries, Norway, India and G7 countries to name a few. Majority of the research done on the topic support the hypothesis that oil price movements have an effect on exchange rates.

The earliest studies on the relationship between crude oil process and exchange rates state a strong link between the oil market and currencies. By studying the US real exchange rate, Krugman (1983) shows that the currency of an oil exporting country might appreciate as oil prices rise and accordingly depreciate as oil prices decrease. On contrary, the currency of an oil importing country is likely to depreciate as oil prices rise and appreciate as oil prices decrease.

Golub (1983) presents similar results as Krugman, only using the US dollar and Deutsche Mark exchange rate. The study states that an increase in oil prices generates a surplus for oil exporters and a deficit for oil importers. The possible reason for exchange rate movements stems from the reallocation of wealth.

Amano and van Norden (1998) continue the previous studies by tackling the limitations the earlier tests and methods have had and also expands the research into causality. They treat crude oil as an exogenous variable due to its historical nature as being dominated by major persistent shocks. The results for U.S. dollar, Yen and D-Mark indicate that the price of oil Granger-causes the real exchange rate. However, no evidence is found of the reverse.

Sadorsky (2000) uses crude oil futures prices and the trade-weighted US Dollar exchange rate to test the co-integration of the two terms. The results state that changes in exchange rates impact oil prices and they support the short-run effect. According to

the result from the vector error correction model, in the long run, a 1% increase in the exchange rates lowers crude oil futures prices by 0.37%.

Akram (2004) finds the relationship between oil prices and Norwegian exchange rate. Norway is one of the major oil exporters in the world and the Norwegian currency is krone. The common theory suggests that major changes in the value of krone have been caused by large fluctuation in the oil prices. Akram finds strong negative relationship between the Norwegian krone and crude oil prices. Interestingly, the strength of the relationship depends on the level and the trend of the price. If the oil prices are particularly low, the changes in the prices affect the exchange rate stronger. Also, as the oil prices are falling the effect becomes stronger as the possibility for particularly lower prices becomes larger. On the other hand, Akram's results show that with high oil prices the effect from the changes in oil prices does not affect exchange rates and if they do, the effect is negligible unless the oil prices are showing a decreasing trend. The results apply in the short run. The study cannot prove significant effects from the oil price movements on the exchange rates in the long run.

To add up more than one country and currency to the study, Chen and Chen (2007) investigate the long-run relationship between real oil prices and real exchange rates in G7 countries. Using monthly data from January 1972 to October 2005 they find a link between the oil prices and exchange rates. Their panel data results show that the real oil prices are major source of the movements in the real exchange rates. They also suggest that real oil prices can significantly forecast future real exchange returns.

Supporting the negative relationship between crude oil prices and the U.S. Dollar exchange rate, Lizardo and Mollick (2010) provide evidence on the negative linkage. They use monthly data of nominal exchange rates, oil price and US monetary supply relative to the foreign money supply from the 1970's to 2008 and apply the monetary approach. The approach is applied on few net oil importers and net oil exporters that are active trade partners with USA. The study argues that in the long-run crude oil prices significantly contribute to the movements in the value of USD. By investigating the exchange rates of oil exporting countries Canada, Mexico and Russia, the results show

that an increase in the oil price leads to a depreciation of the US Dollar against the oil exporter country's currency. On the contrary, oil importers such as Japan suffer a depreciation of their own currency relative to the U.S. Dollar in a similar situation. They also support the predictive nature of oil for USD-based exchange rates.

A study by Reboredo (2012) continues the previous findings. The focus is on the dependence structure of oil and exchange rate. The co-movements in the oil and currency markets are held as a base for the examination. The data used includes daily observations for exchange rates of USD against foreign currencies in a time period from January 2000 to June 2010. By using correlations and copulas as the measures of independency, a general weak dependence is found between oil price and exchange rate. Also, no extreme value dependence is found.

The link between oil price movements and exchange rates can be seen in emerging markets also. Emerging markets are growing fast in terms of GDP. As they are growing, they are using natural resources, such as crude oil, more and more. Their part of the world's total consumption increases continually. Supporting the results of Krugman (1983), another study finds similar results. Using monthly data from 1988 to 2008 on oil prices, exchange rates, oil production and emerging market stock prices and applying the structural VAR model, the study finds a significant impact of a positive oil price shock leads to an immediate decline in exchange rates. The results support the effects in the short run. On the other hand, the study doesn't support the view that oil prices would be impacted by shocks to exchange rates. (Basher, Haug and Sadorsky 2012.)

One of the most recent studies on the correlation between crude oil prices and exchange rates by Li, Lu and Zhou (2016) investigates the relationship from the point of view of five oil rich economies including Australia, Canada, Mexico, Russia and South Africa. By doing a cross-correlation and rolling window analysis between the five series pairs, Li et al. show that in the short run, the cross-correlations of small fluctuations are persistent and those of large fluctuations are anti-persistent. In the long run, the cross correlations act like in the short run except for Russian Rubles that are persistent in both



large and small fluctuations. Strong multifractality between the markets is found in both short- and long-terms.

The law of one price (LOOP) can explain the pattern of exchange rate movements correlating with oil prices. LOOP means that a good has a same price in each country's home currency. The explanation is based on the assumption that commodities like oil are homogeneous enough and they are traded internationally and on the fact that crude oil market is invoiced and settled in US dollars. (Bloomberg & Harris 1995.)

According to Bloomberg and Harris (1995) commodity price movements result from movements in the US dollar. There are two reasons why commodity prices can increase. First, after a downturn or recession in the economy, prices tend to return to their normal levels as a rebound. Second, a weak USD against another currency makes consumers outside USA more willing to pay more dollars for the good. As their purchasing power has increased along with the demand for crude oil, the price of crude oil in US dollars will be pushed up. It is the basic law of demand and supply. As the supply of US dollars increases, its price decreases. (Bloomberg & Harris 1995.)

#### 4. DATA AND METHODOLOGY

This chapter will be presenting the data and methodology used in the thesis. First the data will be analyzed and then the time series' analyses used are presented. The objective is to provide a good overview over the process for the following chapter presenting the empirical results.

The crude oil price data and the exchange rates used for the empirical analysis are retrieved from DataStream. The time period of the research extends from the beginning of January 2006 to the end of August 2016. The period of ten years includes the last moments of upswing in the economy before the financial crisis of 2007-2008 and the recovery from that crisis. Also the time period of early 2016 with the record low oil prices in the last ten years is included in the sample.

In the earlier related works, different time spans have been used. The intervals vary from quarterly data to 5 minutes data. The decision on the use of daily data stems from the volatile nature of both crude oil prices and exchange rates. Daily observations are suitable because crude oil prices and exchange rates are reactive.

##### 4.1. Descriptive statistics

Presenting the data in graphs will give a better overview on the development of the variable and the possible trend it follows. Figure 1 shows how the prices of Brent Crude and West Texas Intermediate have developed during the analysis period from January 2<sup>nd</sup> 2006 until August 28<sup>th</sup> 2016. The crude oil series seem to co-move together from the beginning of the analysis period until the late 2010. After that until the mid 2015 the price of Brent outperforms the price of WTI.



**Figure 1.** Prices of Brent Crude and West Texas Intermediate.

Also, the pattern from boom to bust can be seen in the period from 2007 to 2009. During a time period of one and a half years, the Brent and WTI prices double. The deep plunge in the prices of both of the crude oils demonstrates the effects of the financial crisis of 2007-2008. From the record high prices of over 140 dollars per barrel on both crude oils in June 2008 the prices drop in half a year by around 70 per cent reaching the record low prices of around 40 dollars per barrel. The prices reached and were at around the same level in the early 2016 as they were right after the financial crisis.

The development of USD/NOK exchange rate during the analysis period from January 2006 to August 2016 is pictured in the figure 2. NOK has its strongest value against USD in the summer 2008 when oil price reached the historical highest price. In the summer 2008 oil price collapsed as can be seen in figure 1. Simultaneously NOK depreciated. For the following couple of years the development of the exchange rate was relatively steady due to the stable oil market. In the summer of 2014 as the oil prices started to decrease again, NOK depreciated against USD.



**Figure 2.** Development of USD/NOK exchange rate.



**Figure 3.** Development of USD/CAD exchange rate.

The development of USD/CAD exchange rate pictured in figure 3 shows similar development path as the USD/NOK exchange rate during the time period investigated. Like NOK, CAD also seems to react to changes in crude oil prices.

## 4.2. Unit root tests

Stationarity is crucial to empirical time series analysis. Empirical analysis is based on stationary processes. In most cases time series are non-stationary, which applies to a situation where the joint probability distribution doesn't change over time. As stationarity is a basic assumption in statistical procedures when doing time series analysis, non-stationary data needs to be transformed into stationary data. The presence of a unit root or a trend violates stationarity. It is hard to apply an accurate regression model for non-stationary time series. Also, the further tests done on the non-stationary time series give inaccurate results and do not indicate the actual correlation or causality. (Granger & Newbold 1986.)

Prior to the testing of the evidence on the causal relationship of crude oil prices and exchange rates, an error correction model needs to be applied. A unit root test is used for testing the hypothesis of whether a unit root is present in a time series sample. If the process has a unit root, the time series is non-stationary and if it doesn't have, the time series is stationary.

A stationary time series is a series that is not dependent on the time period the series is representing. No trend or seasonality is affecting the time series. On the other hand, cycles in time series do not make the series non-stationary. Cyclical behavior in a time series can be seen as stationary. Cycles differ from trends and seasonality in their undefined length. For trends and seasonality, the effect can be defined affecting the time series for a certain period. (Mahadeva & Robinson 2004.)

If a unit root is present, the process needs to be differenced to become stationary. The time series' order of integration,  $I(d)$ , indicates how many times it needs to be differentiated.  $I(d)$  indicates  $d$  unit roots. A stationary time series is noted as  $I(0)$ . Two series with orders of integration of  $I(1)$  can be co-integrated only if there is a genuine relationship between the two time series. (Granger & Newbold 1986.)

#### 4.2.1. Augmented Dickey-Fuller test

In accordance with Amano & van Norden (1998) and many other researchers, the augmented Dickey-Fuller (ADF) test will be applied to test the presence of the unit root. The ADF-test is an extended version of the original Dickey-Fuller test that was introduced in 1979 by Dickey and Fuller. ADF-test removes the structural effects in the time series and uses the same procedure for testing as the original version. ADF-test allows for higher-order autoregressive processes.

The three different regression equations of the initial Dickey-Fuller test are the following:

$$(2) \quad \Delta y_t = \gamma y_{t-1} + \varepsilon_t,$$

$$(3) \quad \Delta y_t = a_0 + \gamma y_{t-1} + \varepsilon_t,$$

$$(4) \quad \Delta y_t = a_0 + \gamma y_{t-1} + a_2 t + \varepsilon_t.$$

The first regression accounts for a pure random walk, the second regression includes a drift ( $a_0$ ) and the third regression includes a drift ( $a_0$ ) and a deterministic time trend ( $a_2 t$ ). The number of lags will be determined in accordance of the Akaike's Information Criterion (AIC).

The testing procedure for ADF differs somewhat from the initial Dickey-Fuller test. ADF applies the following model:

$$(5) \quad y_t = \mu_0 + \gamma y_{t-1} + \beta_1 \Delta y_{t-1} + \dots + \beta_{p-1} \Delta y_{t-p+1} + \varepsilon_t,$$

where

$y_t$  = the factor investigated for a unit root

$\mu_0$  = a constant drift term

$\gamma$ =the parameter of interest

$\varepsilon_t$ =the error term

The augmented Dickey-Fuller test tests the following hypothesis:

$$H_0: \gamma=0 \text{ \&}$$

$$H_1: \gamma<0,$$

where  $H_0$  is the null hypothesis meaning that  $y_t$  has a unit root and it is non-stationary and  $H_1$  is the alternate hypothesis meaning that  $y_t$  doesn't have a unit root and it is stationary. (Amano & van Norden 1998.)

#### 4.2.2. Phillips Perron

Another unit root test, a Phillips Perron test (PP test) is applied in order to check the accuracy of the augmented Dickey-Fuller test. If a variable of order of integration noted as  $I(1)$ , a unit root variable is regressed on a stationary variable, noted as  $I(0)$ , the regression presents false results. Variables that are not related will bring out coefficients incorrectly statistically significant as regressed. (Brent & Williams 2007: 35.)

Phillips Perron test differentiates from ADF-test in parametric sense. PP test is non-parametric, meaning that the level of serial correlation doesn't need to be selected. The PP test corrects for serial correlation and heteroskedasticity in the errors. The PP tests are robust to general forms of heteroskedasticity in the error term.

The PP test involves fitting the regression:

$$(6) \quad y_t = \alpha + \rho y_{t-1} + \varepsilon_t$$

where the constant can be excluded or a trend term can be included. The results are used for calculating the t-statistics.

### 4.3. Co-integration

Co-integration is a condition where two time series are linked. Over time they move together and maintain the same difference. Co-integration can be tested in order to find out whether a long-run equilibrium exists between two different time series. A variable  $X_t$  is integrated of order  $d$ , denoted as  $X_t \sim I(d)$ . If  $X_t$  and  $Y_t$  are a pair of  $I(d)$  series, a linear combination of

$$(7) \quad Z_t = X_t - AY_t$$

will also be  $I(d)$ . If a constant ( $A$ ) is present so that  $Z_t \sim I(d - b)$ ,  $b > 0$ , the pair of variables  $X_t$  and  $Z_t$  are said to be co-integrated. In such case, a special constraint operates on the long-run components of the series. (Granger & Newbold 1986: 224-225; Engle & Granger 1987.)

The differences between time series that are noted as  $I(0)$  and  $I(1)$  are substantial. If  $X_t \sim I(0)$ , the variance of  $X_t$  is finite. It is only temporarily affected. If  $X_t \sim I(1)$ , the variance of  $X_t$  goes to infinity as time  $t$  goes to infinity. It is affected permanently. To conclude the idea, “the components of vector  $X_t$  are said to be co-integrated of order  $d$ ,  $b$ , denoted  $X_t \sim CI(d, b)$ , if all components of  $X_t$  are  $I(d)$ ; there exists a vector  $A$  ( $\neq 0$ ) so that  $Z_t = A'X_t \sim I(d - b)$ ,  $b > 0$ . The vector  $A$  is called co-integrating vector.” (Engle & Granger 1987). The model used for testing the co-integration is the Engle-Granger two-step method (1987).

#### 4.2.1. Engle-Granger two-step method

A test for co-integration has been introduced by Engle & Granger in 1987. The method is based on the augmented Dickey-Fuller tests. Engle & Granger (1987) illustrate the approach by giving a simplified example of two different time series,  $X_{1t}$  and  $X_{2t}$ . The time series are generated as a function of possibly correlated standard errors  $\varepsilon_{1-t}$  and  $\varepsilon_{2-t}$  according to the model:



$$(8) \quad X_{1t} + \beta X_{2t} = u_{1t}, \quad u_{1t} = u_{1t-1} + \varepsilon_{1t},$$

$$(9) \quad X_{1t} + \alpha X_{2t} = u_{2t}, \quad u_{2t} = \rho u_{2t-1} + \varepsilon_{2t}, \quad \rho < 0.$$

As there are no exogenous variables and the errors are contemporaneously correlated, the parameters  $\alpha$  and  $\beta$  are unidentified. With a reduced form of the model it is possible to make  $X_{1t}$  and  $X_{2t}$  linear combinations of  $u_{1t}$  and  $u_{2t}$ . Hence, the both time series will be noted as  $I(1)$ . (Engle & Granger 1987.)

The procedure for co-integration analysis presented by Engle & Granger involves estimating the long-run relationship between the two time series with the following model:

$$(10) \quad y_t = \beta_0 + \beta_1 x_t + u_t$$

where  $u_t$  is the residual estimated. If  $u_t \sim I(0)$ , meaning it is stationary,  $y_t$  and  $x_t$  are co-integrated. To estimate the OLS residual  $u_t$ , the following equation needs to be applied:

$$(11) \quad \hat{u}_t = y_t - \beta_0 - \beta_1 x_t$$

The residual sequence has a unit root if the ADF-test cannot reject the null hypothesis. On contrary, if the null hypothesis is rejected, the residual is stationary. In such case the time series  $x_t$  and  $y_t$  are co-integrated. In order to decide whether to reject the hypothesis or not, the critical values by MacKinnon (1991) are compared to the t-statistics of the estimate of  $\hat{u}_t$ . (Granger & Newbold 1986: 262-264.)

#### 4.4. Estimating Vector Autoregression model (VAR)

The Vector Autoregression model is used to determine dependencies between different time series. The properties of VAR model are often estimated using Granger Causality test and impulse responses. (Zhang, Fan, Tsai & Wei 2008.)

##### 4.4.1. Granger causality

The causal relationship of two separate time series can be identified by using the Granger Causality test. The test is based on the VAR model. Each estimated VAR model is tested to find out whether a causal relationship exists between the two variables. (Granger 1969.)

Granger causality is applied for determining whether one time series is useful for forecasting another. It is a simple and straightforward method. According to the Granger causality theorem, a variable  $y_t$  is Granger causing another variable  $x_t$  if it's possible to predict better the variable  $y_t$  using all available information about the variable  $x_t$  and not just the lagged values of  $y_t$ . (Granger 1969.)

The results from the Granger causality test can give four different outcomes; there can be a one-way causality where  $y_t$  causes  $x_t$  or the other way around, a two-way causality where  $y_t$  causes  $x_t$  and also  $x_t$  causes  $y_t$ . Also, no causality between the variables can be found. The causality is defined by two principles: i) the cause needs to happen prior to its effect and ii) the cause has unique information about the future values of its effect. The information is something that cannot be retrieved from anywhere else. (Granger 1969.)

When empirically tested, the hypotheses for the Granger causality test in this case are following:

$H_0$ : The crude oil price does not Granger cause the exchange rate

$H_1$ : The exchange rate Granger causes the crude oil price

The first hypothesis relates to the following linear regression:

$$(12) \quad y_t = \alpha_0 + \sum_{i=1}^p \alpha_{11} y_{t-i} + \sum_{i=1}^p \alpha_{12} x_{t-i} + \varepsilon_t$$

The second hypothesis is tested through the following linear regression:

$$(13) \quad x_t = \alpha_0 + \sum_{i=1}^p \alpha_{21} x_{t-i} + \sum_{i=1}^p \alpha_{22} y_{t-i} + \varepsilon_t$$

where  $p$  is the maximum number of lagged observations in the model, the matrixes contain the coefficients and  $\varepsilon_t$  is the error term. (Granger & Newbold 1986.)

To interpret the results from the linear regression models, it can be said that  $x_t$  Granger causes  $y_t$  if the coefficients in matrix  $\alpha_{12}$  are jointly significantly different from zero. To test for it, an F-test can be carried out. The F-test compares the Sum of Squared Errors from the restricted model with the Sum of Squared Errors of the unrestricted model. (Granger & Newbold 1986.)

The model for the F-test is following:

$$(14) \quad F = \frac{\frac{SSE_r - SSE_u}{m}}{\frac{SSE_u}{(n-k)}}$$

where,

$SSE_r$  = the Sum of Squared Error from the restricted model

$SSE_u$  = the Sum of Squared Error of the unrestricted model

$m$  = number of restrictions

$n$  = number of observations

$k$  = total number of parameters estimated in the unrestricted model

After applying the F-test, the result is compared to the critical value. By doing the comparison the null hypothesis can be rejected if the F-values are greater than the critical values of the significance level desired. (Granger & Newbold 1986.)

#### 4.4.2. Impulse response

The Impulse Response is formed to track the responsiveness of variables in the VAR system when a shock from one variable is applied on another variable. The magnitude of the response can be seen in the graphs drawn from the test. The analysis of the impulse response will be useful to trace out the changes in each variables in the following Error Correction Model. (Zhang et al. 2008.)

#### 4.5. Error Correction Model

The Error Correction Model (ECM) can be used to examining the short-term and long-term movements of the variables. The results show whether the changes in one variable move towards changes of the other variable or the other way around. ECM directly estimates the speed at which the dependent variable returns to equilibrium after a change in the other variable. (Engle & Granger 1987.)

The ECM has a close relationship with co-integration. If two variables are co-integrated, the co-integrating vector indicates the long-term equilibrium. According to Engle and Granger (1987), the time series studied in the model need to be integrated of same order,  $CI(1,1)$ . The ECM is formed from the VAR model and the equations are added the error correction term. The residuals from the co-integration equation can be used as the error correction term. (Engle & Granger 1987.)

The time series will have the following form of equation:

$$(15) \quad \Delta Y_t = \alpha_1 + \alpha_Y e_{t-1} + \sum_{i=1}^q \alpha_{11(i)} \Delta Y_{t-i} + \sum_{i=1}^p \alpha_{12(i)} \Delta X_{t-i} + \varepsilon_{Yt}$$

$$(16) \quad \Delta X_t = \alpha_2 + \alpha_X e_{t-1} + \sum_{i=1}^q \alpha_{21(i)} \Delta Y_{t-i} + \sum_{i=1}^p \alpha_{22(i)} \Delta X_{t-i} + \varepsilon_{Xt}$$

where

$\Delta Y_t$  = differenced variable,

$\Delta X_t$  = differenced variable,

$e_{t-1}$  = the residual from equation (11),

p and q = lag parameters,

$\alpha_1 \dots \alpha_{22}$  = all parameters,

$\varepsilon_{Xt}$  = lagged error term.

## 5. EMPIRICAL ANALYSIS

The results for the analyses applied for the time series are presented in this chapter. The data and the methodology used have been discussed in the previous chapter. Prior to the empirical tests, the research data will be analyzed more carefully in the first section. The tests and analyses are executed by using Eviews.

### 5.1. Statistical properties of the time series

Table 1 presents the descriptive statistics of the data on the flat prices, levels of Brent Crude, West Texas Intermediate, U.S. Dollar against the Norwegian Krone and the Canadian Dollar. The results indicate a higher deviation from the mean for the both oil prices, and lower for the currencies. Especially the data set values of USD/CAD seem to stay close to the mean value.

As for the skewness, the values for the two currencies suggest a substantial skewness and the distribution seems to be far from the symmetrical form when turned into a graph. The values near three for kurtosis for the two currencies at the levels are matching quite well for the Gaussian distribution, known as the normal distribution. On the other hand, the kurtosis values for the both crude oil prices indicate a distribution less peaked and broader central peak and the tails to be shorter and thinner. This phenomenon is stronger for the price of Brent though.

Table 2 includes the same statistical analysis as presented on the levels, but in the second table the data has been turned into returns of the logarithmic time series. By doing this the heteroskedasticity can be eliminated. Also, the logarithmic form of the data will provide values to be relative to one another. Especially, the research data on the currencies USD/CAD and USD/NOK are positively skewed. Turning the data into logarithmic form makes the distribution more normal.

**Table 1.** Descriptive statistics of the flat prices.

LEVELS				
	BRENT	WTI	USD/CAD	USD/NOK
<b>Mean</b>	83,530	78,350	1,099	6,330
<b>Median</b>	79,790	80,220	1,064	6,035
<b>Maximum</b>	145,610	145,310	1,464	8,958
<b>Minimum</b>	27,820	26,190	0,907	4,959
<b>Std. Dev.</b>	26,116	22,678	0,110	0,923
<b>Skewness</b>	-0,064	-0,079	0,933	1,238
<b>Kurtosis</b>	1,8014	2,448	2,952	3,610
<b>Observations</b>	2728	2728	2728	2728

**Table 2.** Descriptive statistics of the returns.

RETURNS				
	BRENT	WTI	USD/CAD	USD/NOK
<b>Mean</b>	-0,000	-0,000	0,000	0,000
<b>Median</b>	0,000	0,000	-0,000	-0,000
<b>Maximum</b>	0,135	0,191	0,036	0,044
<b>Minimum</b>	-0,111	-0,128	-0,044	-0,059
<b>Std. Dev.</b>	0,020	0,025	0,007	0,008
<b>Skewness</b>	0,201	0,231	0,126	0,084
<b>Kurtosis</b>	6,614	8,519	6,363	6,026
<b>Observations</b>	2727	2727	2727	2727

In addition to the conversion into logarithmic form, the returns time series is used. This is done by calculating the change between the value  $t$  and the value  $t+1$ . The equation for the returns is the following:

$$(17) \quad \Delta y = \ln \left( \frac{y_t}{y_{t-1}} \right)$$

where

$y_t$  = the value in the data set at time  $t$

$\Delta y$  = the return.

Calculating the skewness for the logarithmic returns, Table 2 gives values near zero. This means that the distribution is approximately symmetric. Normal distribution has the kurtosis value of three. Interpreting the results for the logarithmic returns, an excess kurtosis can be seen in the values. This suggests that compared to the normal distribution, the peak is higher and the tails of the distribution are longer and flatter. Standard deviation in Table 2 indicates the values of the data set to be close to the mean.

#### 5.1.1. Correlation

Next step analyzing the data is to run a simple correlation test. In accordance with Cifarelli & Paladino (2010), Akram (2004) and Yousefi & Wirjanto (2004), the correlation between crude oil prices and the U.S. Dollar values against major oil exporter currencies is negative. The other side of the currencies, the values of the major oil exporter countries against the U.S. Dollar would be positively correlated to crude oil prices. In accordance with Zhang, et al. (2008), the correlation test is run with the lagged values of the time series. The lagged periods are one and two periods, which is one and two days in the daily data sets used.

Table 3 presents the correlation coefficients for the chosen crude oil Brent and the U.S. Dollar value against the Canadian Dollar. Table 4 compares Brent and the U.S. Dollar against the Norwegian Krone. Table 5 presents the coefficients for the correlation of WTI and USD/CAD. Table 6 presents the results for WTI and USD/NOK. All in all the entire correlation coefficient group is strongly significant and give large negative relationship results for all the variable pairs.



The negative correlations in all tables from 3 to 6 indicate, that as the crude oil price increases, the value of the exchange rate depreciates and vice versa. The strongest negative correlation seems to be between USD/CAD and Brent and WTI that are presented in tables 3 and 5 respectively. The difference whether the other variable is WTI or Brent in the case of USD/CAD is quite irrelevant. The correlation seems to be as strong in both cases. Though, with WTI and USD/CAD the lagged periods don't seem to affect the strength of the correlation. With Brent and USD/CAD the strength of the correlation is greater with lagged period of two.

The exchange rate USD/NOK presents different correlation coefficients when regressed with WTI and Brent. As can be seen in table 4, the coefficients are lower with Brent than in table 6 with WTI. USD/NOK negatively correlates stronger with WTI. The lags also make a little difference in both correlations, the greater the lag the stronger the correlation.

**Table 3.** Lagged correlation between BRENT and USD/CAD.

	<b>BRENT</b>	<b>BRENT-1</b>	<b>BRENT-2</b>
<b>USD/CAD</b>	-0,8390	-0,8374	-0,8350
<b>USD/CAD-1</b>	-0,8395	-0,8390	-0,8373
<b>USD/CAD-2</b>	-0,8398	-0,8394	-0,8389

**Table 4.** Lagged correlation between BRENT and USD/NOK.

	<b>BRENT</b>	<b>BRENT-1</b>	<b>BRENT-2</b>
<b>USD/NOK</b>	-0,7802	-0,7785	-0,7765
<b>USD/NOK-1</b>	-0,7807	-0,7801	-0,7784
<b>USD/NOK-2</b>	-0,7811	-0,7806	-0,7799

**Table 5.** Lagged correlation between WTI and USD/CAD.

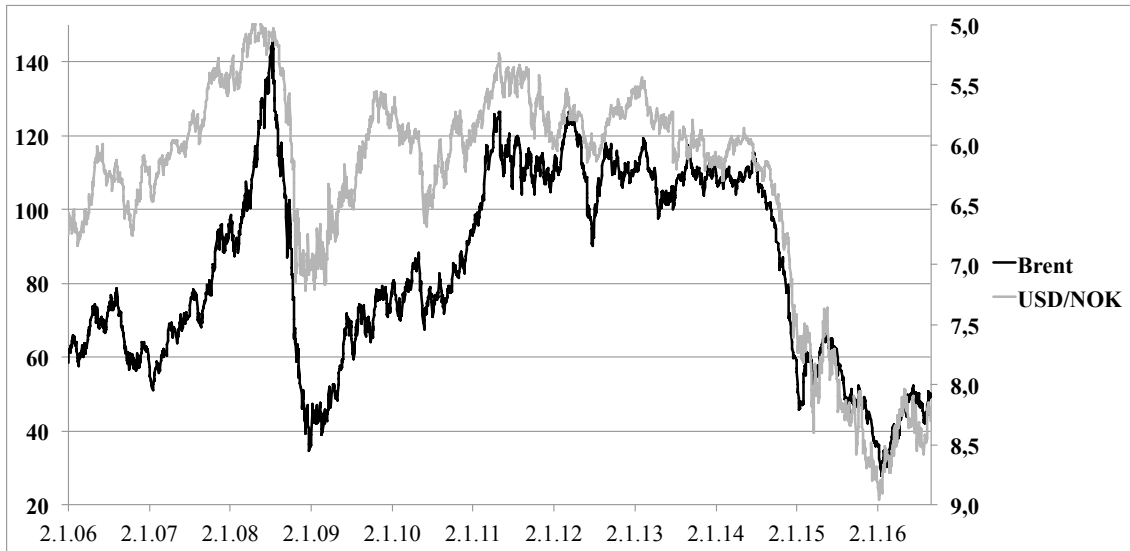
	<b>WTI</b>	<b>WTI-1</b>	<b>WTI-2</b>
<b>USD/CAD</b>	-0,8393	-0,8381	-0,8357
<b>USD/CAD-1</b>	-0,8393	-0,8392	-0,8380
<b>USD/CAD-2</b>	-0,8393	-0,8392	-0,8391

**Table 6.** Lagged correlation between WTI and USD/NOK.

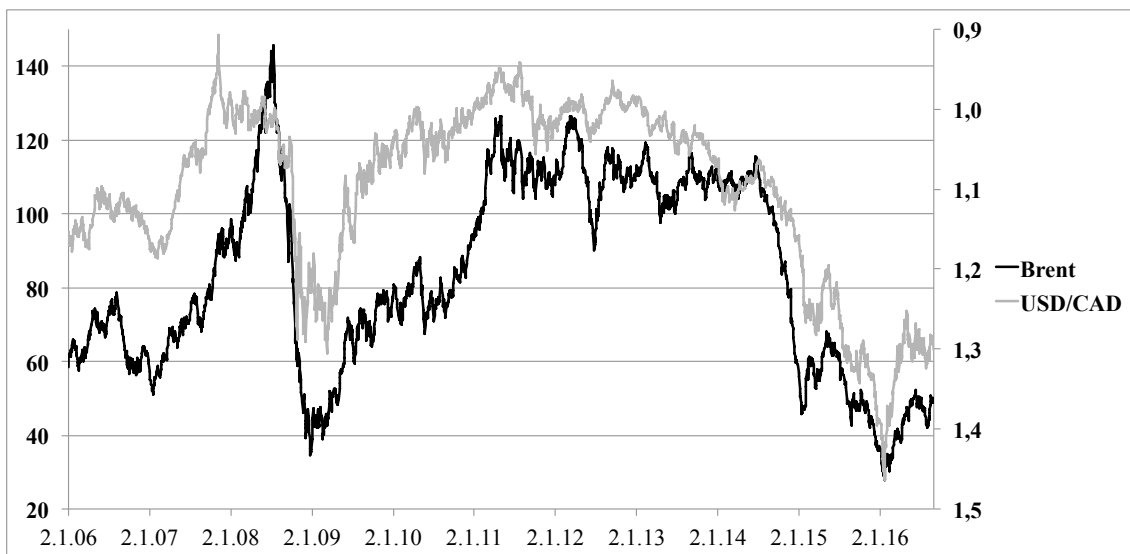
	<b>WTI</b>	<b>WTI-1</b>	<b>WTI-2</b>
<b>USD/NOK</b>	-0,8222	-0,8207	-0,8183
<b>USD/NOK-1</b>	-0,8226	-0,8221	-0,8206
<b>USD/NOK-2</b>	-0,8229	-0,8225	-0,8220

The figures from 4 to 7 present the relationships between the currencies and the crude oil prices in graphic form. The right axis presenting the exchange rates has been turned upside down in all the figures. This is due to the easier interpretation of the relationship. With a negative relationship, the strength of the opposite movement of the variables is easier to see with the exchange rate axis upside down.

Figure 4 graphs the relationship between Brent and USD/NOK. The time series seems to move together closely especially in the end half of the researched time period after 2010. After the hit of the financial crisis in 2007-2008 USD/NOK seems to follow the movements of Brent with a little lag in the major movements. Figure 6 graphs the relationship between USD/NOK and WTI. The path is similar to figure 4. Especially from the beginning of 2014 the time series are overlapping each other moving tightly together.

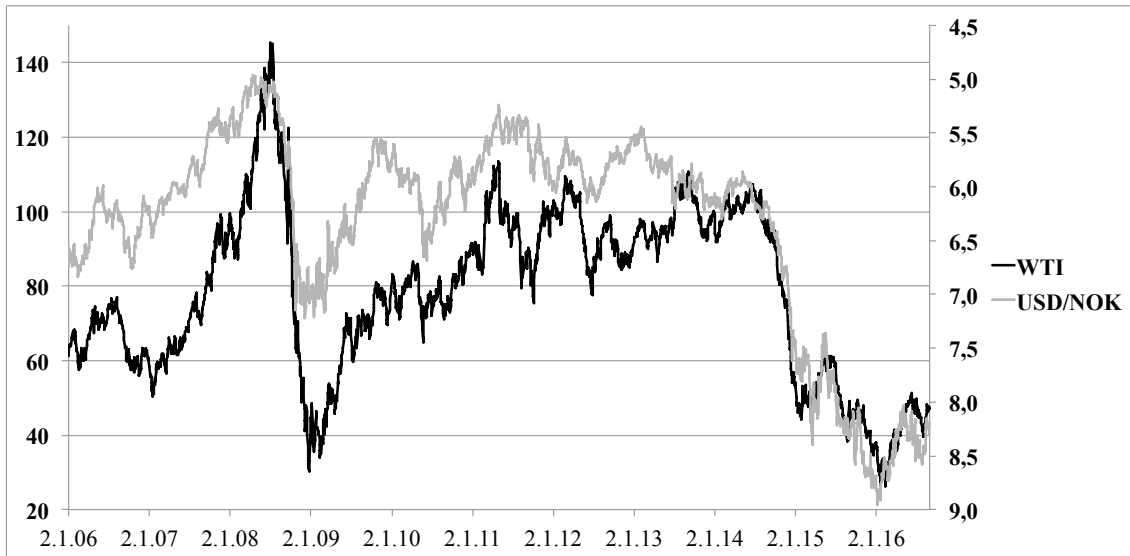


**Figure 4.** Development of Brent & USD/NOK.

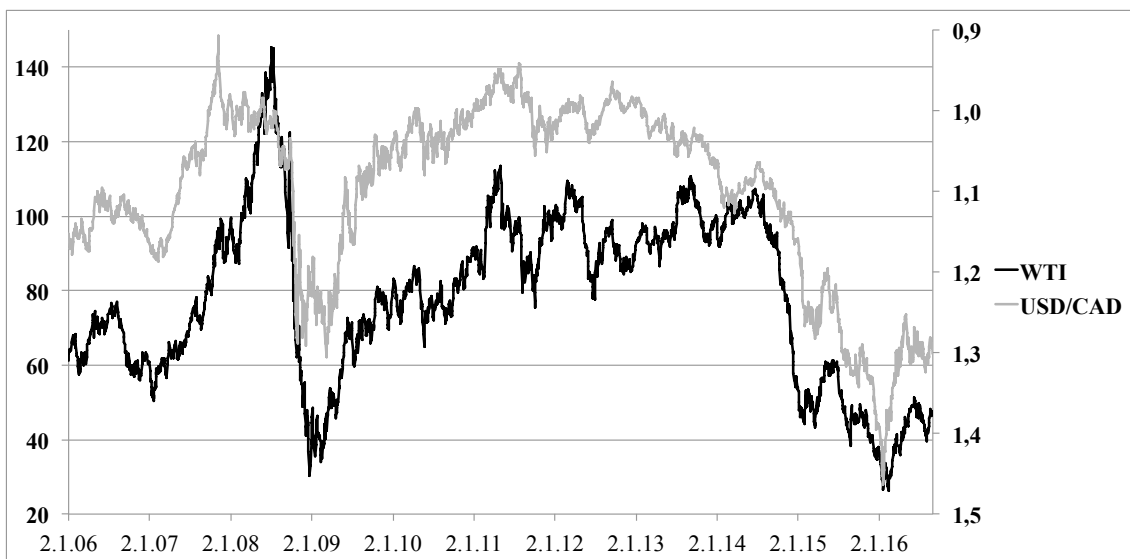


**Figure 5.** Development of Brent & USD/CAD.

Figures 5 and 7 present the relationship between USD/CAD and Brent and USD/CAD and WTI respectively. The paths in both graphs follow closely the movements of each other. Notable differences between the graphs cannot be seen.



**Figure 6.** Development of WTI & USD/NOK.



**Figure 7.** Development of WTI & USD/CAD.

## 5.2. Unit root tests

The basic time series analysis is based on stationary data. A stationary data refers to research data that doesn't have a unit root. If a unit root exists, the data needs to be

differentiated to become stationary. The methods behind the tests have been presented in chapter 4.

### 5.2.1. Augmented Dickey-Fuller test

The Augmented Dickey-Fuller test (ADF-test) is used to examine the existence of a unit root. The ADF-test is run on logarithmic data on both levels and at the first difference. The lag length was selected using the AIC criterion. Table 7 shows the results for the ADF-test.

**Table 7.** Results from the ADF-test.

ADF-test	At Level	First Difference
<b>LNBRENT</b>	-0,348	-11,414
<b>LNWTI</b>	-0,399	-13,656
<b>LNUSD/CAD</b>	0,408	-17,606
<b>LNUSD/NOK</b>	0,408	-53,243
<b>CRITICAL VALUES</b>		
<b>At 1% level</b>	-2,566	
<b>At 5% level</b>	-1,941	
<b>At 10% level</b>	-1,617	

The t-statistics for the level values for the logarithmic time series are higher than the p-values at even the 10% level. This indicates a non-stationary for all the four time series. According to the results, the null hypothesis of the presence of a unit root cannot be rejected. The first difference of the time series is stationary meaning that the variables are integrated of order 1,  $I(1)$ .

### 5.2.2. Phillips Perron test

Another unit root test is applied to confirm the results from the ADF-test. The results from the Phillips Perron test are reposted in Table 8. The results from the PP-test are in

line with the ADF-test applied before and confirm the results. The PP-test also suggests that the data needs to be differenced once to reach stationary. Since the variable time series are all integrated of order one,  $I(1)$ , it can be assumed that also co-integration at least between some of the time series can be found.

**Table 8.** Results from the PP-test.

PP-test	At Level	First Difference
<b>LN Brent</b>	-0,265	-50,856
<b>LNWTI</b>	-0,336	-54,180
<b>LNUSD/CAD</b>	-0,767	-53,758
<b>LNUSD/NOK</b>	0,448	-53,340
<b>CRITICAL VALUES</b>		
<b>At 1% level</b>	-2,566	
<b>At 5% level</b>	-1,941	
<b>At 10% level</b>	-1,617	

### 5.3. Co-integration

The co-integration of the time series is tested. The time series' integration of same order is essential for proceeding to further tests. The results for the ADF-test and the PP-test suggest that all the variables are integrated of same order,  $I(1)$ . To test co-integration, the method proposed by Engle & Granger (1987) is applied.

#### 5.3.1. Engle-Granger two-step method

The integration of the time series of same order is the base for the co-integration. If the integration isn't of same order between the time series, no co-integration exists. After establishing the integration of same order between the variables, a test for the long-run equilibrium is applied. The residuals from the equation presented in chapter 4 needs to

be stationary. The long-run equilibrium of the time series exists if the equilibrium error process is stationary.

First, the residuals of the equation are calculated using Ordinary Least Square regression. Then the ADF-test is run on the residuals to test whether a unit root exists. The critical values of MacKinnon (1991) are compared to the results from the residuals ADF-test instead of the values given in the ADF-test itself.

The Engle-Granger two-step method for co-integration testing has been criticized of not indicating the independent and dependent variable. Therefore the tests are run both ways, pairing the time series as USD/NOK-BRENT, BRENT-USD/NOK, USD/CAD-WTI and WTI-USD/CAD. Lags are again determined using the Akaike's information criteria.

**Table 9.** Engle-Granger stationary test on residuals.

<b>OLS REGRESSION ON RESIDUALS</b>		
	<b>ADF-TEST VALUE</b>	<b>CO-INTEGRATED</b>
<b>USD/NOK-BRENT</b>	-39,555	Yes
<b>BRENT-USD/NOK</b>	-53,833	Yes
<b>USD/CAD-WTI</b>	-18,232	Yes
<b>WTI-USD/CAD</b>	-14,032	Yes
<b>MacKinnon (1991) critical values</b>		
<b>At 1% level</b>	-3,900	
<b>At 5% level</b>	-3,338	
<b>At 10% level</b>	-3,046	

Results for the co-integration tests are presented in Table 9. Results indicate that all the time series paired up are co-integrated at 1% significance level comparing with the values of MacKinnon (1991). The null hypothesis of a unit root is rejected for all the

significant pairs and that makes the pairs co-integrated. The results suggest that the pairs move together in the long-term.

The results for the correlation of the returns presented in Table 3 suggest that USD/CAD correlates at quite the same magnitude with both crude oils, Brent and WTI. Also, as the correlation between the crude oils and USD/NOK does not differ drastically whether looking at Brent or WTI, co-integration is also tested on pairs of USD/NOK-WTI, WTI-USD/NOK, USD/CAD-BRENT and BRENT-USD/CAD.

The results for the other stationary test on residuals are presented in Table 10. They indicate co-integration between all tested the time series pairs, USD/NOK-WTI, WTI-USD/NOK, USD/CAD-BRENT and BRENT-USD/CAD. To conclude, the both crude oils, WTI and Brent, are co-integrated with the U.S. Dollar exchange rate against the Canadian Dollar and the Norwegian Krone.

**Table 10.** Engle-Granger stationary test on residuals.

<b>OLS REGRESSION ON RESIDUALS</b>		
	<b>ADF-TEST VALUE</b>	<b>CO-INTEGRATED</b>
<b>USD/NOK-WTI</b>	-39,408	Yes
<b>WTI-USD/NOK</b>	-11,475	Yes
<b>USD/CAD-BRENT</b>	-18,377	Yes
<b>BRENT-USD/CAD</b>	-54,271	Yes
<b>MacKinnon (1991) critical values</b>		
<b>At 1% level</b>	-3,900	
<b>At 5% level</b>	-3,338	
<b>At 10% level</b>	-3,046	



#### 5.4. VAR model

After finding co-integration between both of the crude oils and both exchange rates, the construction of the VAR model is applicable. The optimal lagged period is estimated by using the least Akaike's information criterion (AIC) and Schwarz's information criterion (SIC) values. The VAR model is run on crude oil-currency pairs separately. For all the pairs both AIC and SIC values are the lowest when two lags are included. The optimal lagged period is therefore set to two.

##### 5.4.1. Results of the Granger Causality method

The Granger Causality test is based on VAR model. The equations 11 and 12 are run with lagged period of two ( $p=2$ ). The results for the levels are presented in Table 12.

**Table 11.** Results of the Granger Causality test.

Null Hypothesis	<i>F</i> -statistics	Probability
BRENT does not Granger Cause USD/NOK	30,439	0,000
USD/NOK does not Granger Cause BRENT	6,701	0,001
WTI does not Granger Cause USD/NOK	64,984	0,000
USD/NOK does not Granger Cause WTI	8,679	0,000
BRENT does not Granger Cause USD/CAD	48,752	0,000
USD/CAD does not Granger Cause BRENT	6,907	0,001
WTI does not Granger Cause USD/CAD	85,674	0,000
USD/CAD does not Granger Cause WTI	7,555	0,001

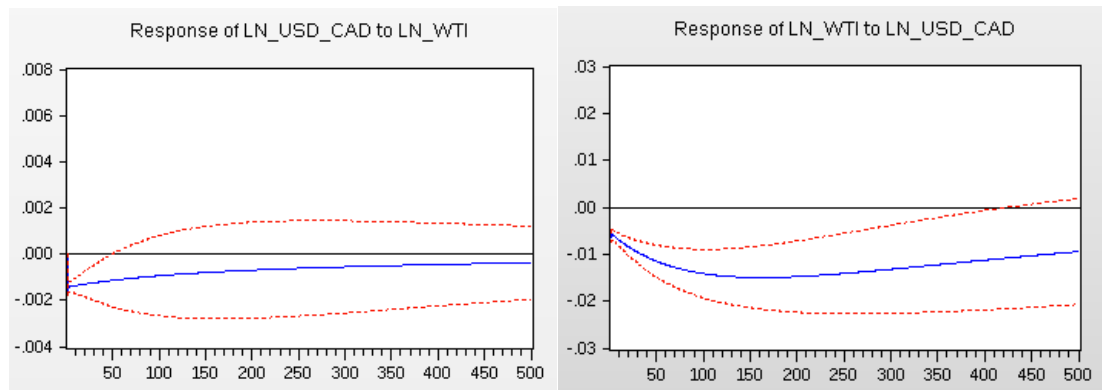
Table 12 indicates significant results on the p-values on 1%, 5% and 10% level as the p-value is close to zero. Therefore all the null hypotheses are rejected even at the 1% level. This suggests a strong bidirectional causal relationship between the pairs Brent-USD/NOK, WTI-USD/NOK, Brent-USD/CAD and WTI-USD/CAD. This means for example that a change in the price of Brent does Granger Cause the exchange rate of USD/NOK to change and vice versa.

The two-way causal relationships between crude oil prices and exchange rates seem to run stronger from the crude oil to the exchange rate in all cases than the other way around. The results indicating the bidirectional causal relationships are in accordance with Fratzscher, Schneider and Van Robays (2014).

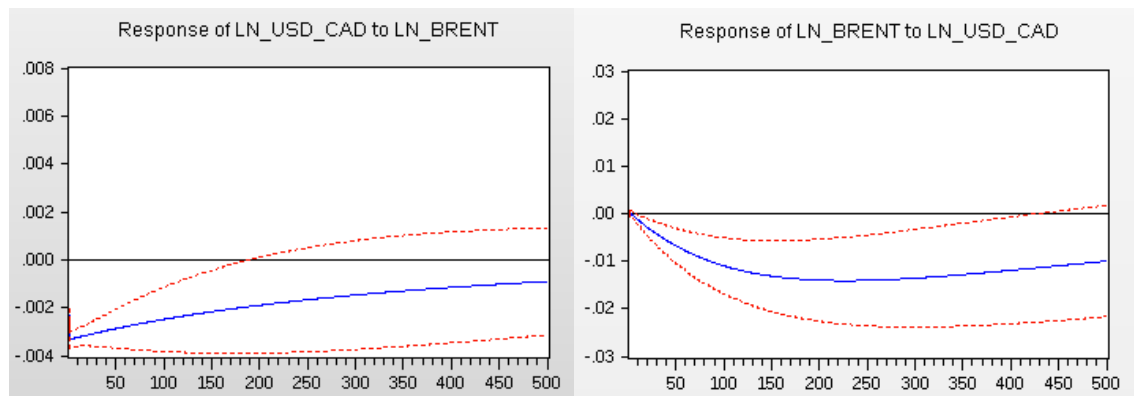
#### 5.4.2. Results of the Impulse Response Model

The impulse response function can be used for variables to determine the magnitude of the response to the impulse of one standard deviation of the disturbance. The impulse response model is run with the period of 500. Using the daily data, the period length of 500 means 500 days. This period selection is in accordance with Zhang et al. (2008).

**Table 12.** Impulse responses of USD/CAD to WTI and WTI to USD/CAD.

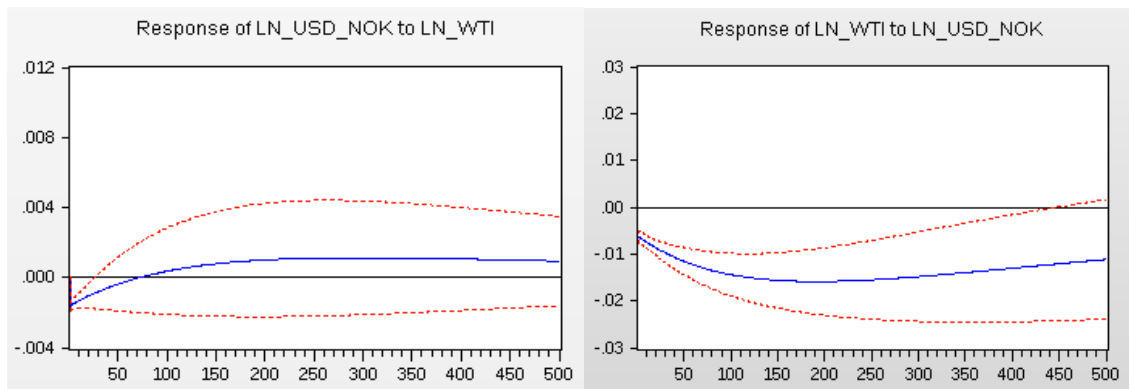


**Table 13.** Impulse responses of USD/CAD to BRENT and BRENT to USD/CAD.

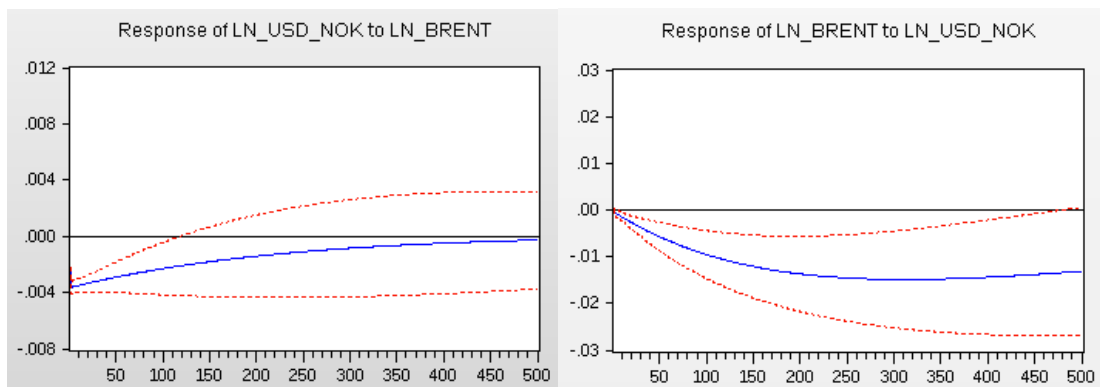


Tables 13 and 14 present the results for the responses of USD/CAD exchange rate and WTI and Brent respectively. In the left picture in Table 13, the one standard deviation positive shock in the impulse factor WTI decreases the response factor USD/CAD. The effect eases and eventually turns towards zero. The effect is adjusting after the about 1 year (234 trading days). On the right picture in Table 13 the one standard deviation positive shock in the impulse factor USD/CAD decreases the response factor WTI. The effect is greater than the other way around. The price of WTI keeps decreasing for the first 150 day and then slowly turns into a slight increase. Table 14 indicates very similar results in the case of USD/CAD compared to Brent crude. The left picture in table 14 indicates a little stronger effect of the positive shock in Brent on USD/CAD than is the case with WTI. Similarly, in the right picture in Table 14, the decreasing effect of a positive shock in USD/CAD on Brent lasts until around the 200<sup>th</sup> trading day.

**Table 14.** Impulse responses of USD/NOK to WTI and WTI to USD/NOK.



**Table 15.** Impulse responses of USD/NOK to BRENT and BRENT to USD/NOK.



Tables 15 and 16 present the impulse response results for the USD/NOK exchange rate and WTI and Brent respectively. USD/NOK exchange rate seems to differ from USD/CAD in its response to positive shocks in both WTI and Brent. Picture on the left in Table 15 indicates that the immediate response of USD/NOK is a decrease but the effect turns positive after about 70 trading days. The same situation with Brent does not become positive but turns close to zero when the 500<sup>th</sup> trading day gets close. Brent and WTI response to one standard deviation positive shock in USD/NOK with a decrease. The right pictures in Tables 15 and 16 indicate a different length of the response period. In the case with WTI, the effect lasts around 200 trading days until the curve starts to converge back towards zero. The effect period in the case of Brent is longer; it seems to last for about 1 year, 300 trading days.

All in all, the impulse response graphs support the earlier results for the negative relationship between the time series. Also, the results of bidirectional causality relationship from the Granger Causality test are confirmed by the graphs. The effect seems to work two-ways.

### 5.5. Results of the Error Correction Model

As all the tested pairs are co-integrated according to the Engle-Granger two-step method, the construction of the Error Correction Model is applicable for all the pairs. The ECM is also suitable as there is only one independent variable in each estimation. Estimation of the ECM is done by OLS regression.

Table 17 presents the error correction terms for the run regression presented earlier. The results indicate similar results for the significant ECT's as the correlation tests. The coefficients of the ECT's are all negative except for the USD/NOK over Brent and significant at 1% level for the pairs Brent & USD/CAD, Brent & USD/NOK, WTI &

USD/CAD and WTI & USD/NOK. This indicates that the long-term equilibrium exists between the significant pairs mentioned.

The ECM test results confirm half of the suggestions of the Granger Causality test. The Granger Causality test indicated a strong and significant bidirectional relationship between all the pairs tested, though the relationship tends to run stronger from the oil prices to exchange rates. ECM results indicate that the equilibrium holds only for the pairs for which the crude oil is determined as the dependent variable.

The results suggest that both of the dependent variables Brent and WTI have a strong and significant predicting power over the independent variables, the exchange rates of USD/CAD and USD/NOK.

**Table 16.** Results from ECM.

<b>Dependent variable</b>	<b>Independent variable</b>	<b>ECT</b>	<b>T-statistics</b>	<b>p-value</b>
BRENT	USD/CAD	-0,009	-3,840	0,000
BRENT	USD/NOK	-0,007	-3,652	0,000
USD/CAD	BRENT	-0,002	-0,632	0,528
USD/NOK	BRENT	0,001	0,355	0,723
WTI	USD/CAD	-0,015	-4,020	0,000
WTI	USD/NOK	-0,013	-4,455	0,000
USD/CAD	WTI	-0,003	-0,958	0,338
USD/NOK	WTI	0,001	0,488	0,626

## 6. CONCLUSIONS

This thesis studies the relationship between crude oil prices and exchange rates. The data contains a time period of a little over ten years, from January 2<sup>nd</sup> 2006 to August 28<sup>th</sup> 2016. As crude oil, the prices of Brent and WTI are used. The exchange rates of the U.S. Dollar against the Canadian Dollar and the Norwegian Krone were chosen because USD is the invoicing currency of oil and Canada and Norway are major oil exporters and could therefore be easily affected by changes in the market. The relationship is investigated mixing the chosen crude oils and USD exchange rates as pairs.

The first hypothesis suggests the existence of a link between the crude oil price and the exchange rate. The linkage is broadly established in the previous literature. In this thesis, that is proven with the results of the correlation analysis. The results state a strong and significant relationship between all the crude oil and exchange rate combinations. Also, the second hypothesis of a negative relationship between crude oil prices and exchange rates is found. The correlation coefficients are negative and significant. The results indicate that as crude oil prices increase, the USD exchange rates against foreign currency depreciate.

Crude oil prices tend to move together. Figure 1 presents the development of both crude oil benchmarks Brent and WTI. The prices move at the same level from the beginning of the time period, from 2006, until the beginning of 2011. There is a period of a couple years from 2011 to 2014 when the price of Brent exhibits higher values than WTI. Other slight separation in the co-movement happens in the beginning of 2015.

Co-integration of crude oil price and exchange rate is tested with the Engle-Granger two-step method. The results indicate that all the tested pairs are co-integrated. This suggests a strong long-term equilibrium.

The possible causal relationship between crude oil prices and exchange rates is tested with Granger Causality test. Hypothesis three and four state the causal relationship from

crude oil to exchange rates and vice versa, respectively. The Error Correction Model indicates only unidirectional significant relationship running from the crude oil to exchange rates. The results indicate long-term equilibrium for the pairs.

Differences in relationships between the mixed pair combinations of Brent Crude, WTI, USD/CAD and USD/NOK do not appear in large scale. Interpreting the results from the correlation analysis, there is a slight difference in the strength of the correlation. All pairs exhibit strong and significant correlation coefficients but the strongest relationship is between USD/CAD and both the crude oils. The least, yet also strongly correlated pair is Brent and USD/NOK.

In accordance with the majority of the studies on the field, this study exhibits similar results. The link between the crude oil prices and the exchange rates is strong and significant. The negative relationship found indicates that as crude oil prices increase, the exchange rate decreases. Also, the variables studied exhibit co-integration. The causality tests indicate a strong causality running from the crude oil prices to exchange rates. Strong long-term equilibrium is also found.

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